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TECHNICAL MEMORANDUM 1254

A DIGITAL COMPUTER PROGRAM

FOR A

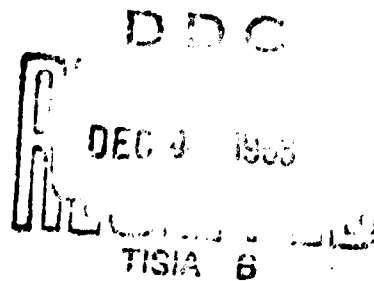
BRUCETON ANALYSIS

FORREST L. MCMAINS

AMCMS 5023.11.18400

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AUGUST 1963



PICATINNY ARSENAL
DOVER, NEW JERSEY

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DIGITAL COMPUTER PROGRAM
FOR A
BRUCETON ANALYSIS

BY

FORREST L. MC MAINS

AMCMS 5023.11.18400

AUGUST 1963

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ABSTRACT

A digital computer program was developed for performing the Bruceton statistical analysis on an IBM 709 or IBM 7090. A brief description of the Bruceton test is given -- followed by an outline of the method of analysis which this program uses. Input and output formats are discussed.

INTRODUCTION

The purpose of this report is to describe a digital computer program which was developed for performing a statistical analysis of sensitivity data obtained from the Bruceton Test.

Part I discusses the input and output formats. Part II discusses the numerical calculations used. The appendix lists the program as written in Fortran.

The Bruceton Test -- developed by the Explosives Research Laboratory at Bruceton, Pennsylvania -- measures electrical sensitivity of an electro-explosive device at a specific level of frequency. The lowest power level should fall above the "no-fire" level for the device being evaluated and the highest power level should fall below the "all-fire" power level. This test is preferable to other similar tests in that it concentrates the testing near the mean. Therefore, in most situations, a desired degree of reliability can be obtained with a smaller sample.

With the data from a Bruceton Test the mean (m) or the 50% firing level and the standard deviation (σ) can be calculated. Further computation yields the extreme probabilities such as the 99.9% and the 0.1% levels. These are expressed with the confidence intervals included.

This statistical analysis is based on the Bruceton Report (Reference 1). It is assumed that the calculations found in Part II will be used in conjunction with the Bruceton Report and the Franklin Institute Memorandum (Reference 2).

DISCUSSION

Part I - Input and Output Formats

A. Input Format

The first ten data cards will be the same for any group of runs. These are constant values (G, H and S) obtained from the graphs found in the Bruceton Report.

Following this set of cards, any number of runs may be included provided each run is in correct sequence.

The format for the first data card is:

Spaces 1 through 20 (inclusive) are reserved for an identification.
Spaces 21-25 are reserved for the number of levels used.
Spaces 26-35 are reserved for the common logarithm of the lowest level.

Spaces 36-45 are reserved for the constant interval between the logarithms of the levels.

Spaces 46-50 are reserved for the probability level (in percent).
Spaces 51-55 are reserved for the confidence level (in percent).
Spaces 56-60 are reserved for the value of the first (lowest) level (in milliwatts).

Spaces 61-65 are reserved for the number of "fires" at that level.
Spaces 66-70 are reserved for the number of "no-fires" at that level.

Spaces 71-80 are blank.

Each successive level, followed by the "fires" and "no-fires" at that level (in that order), are placed on the second card with five spaces reserved for each value. If more data remains after the second card is used; a third, fourth, etc., may be used with the same format.

As a convenience those numbers above, which are whole numbers, need not be written with a decimal.

B. Output Format

The output will list all the input data as well as every intermediary value used in the analysis. The values used in the primary statistics and in the secondary statistics are so labeled.

If P and E equal the input probability and confidence levels respectively, then in the final calculations the values (both in logarithmic units and milliwatts) consist of

P% probability with E% confidence and
(100-P)% probability with E% confidence.

Part II - Numerical Calculations

A. Primary Statistics

Let N equal the number of levels used.

Let X(i), where i=0, 1, 2, ...N, equal the value of each level.

Let $n_x(i)$ equal the number of "fires" at each level.

Let $n_o(i)$ equal the number of "no-fires" at each level.

Let c equal the logarithm of the lowest level.

Let d equal the constant logarithmic interval between levels.

Let P% equal the probability level.

Let E% equal the confidence level.

$$N_x = \sum_i n_x(i)$$

$$N_o = \sum_i n_o(i)$$

$$A_x = \sum_i i n_x(i)$$

$$A_o = \sum_i i n_o(i)$$

$$B_x = \sum_i i^2 n_x(i)$$

$$B_o = \sum_i i^2 n_o(i)$$

$$M_x = \frac{N_x B_x - A_x^2}{N_x^2}$$

$$M_o = \frac{N_o B_o - A_o^2}{N_o^2}$$

$$m_x = c + d \left(\frac{A_x}{B_x} - 1/2 \right)$$

$$m_o = c + d \left(\frac{A_o}{B_o} - 1/2 \right)$$

If $M_x < 0.3$, the smallest absolute value $R = \left| \frac{m_x - \log X(i)}{d} \right|$

is evaluated and Graph I in the Bruceton Report is used to find s_x . Incorporated in the program (data cards 3-10) are 268 points taken from this graph with $M_x = .05, .06, \dots, .30$ and $R = 0, .5, .1, .15, \dots, .5$

Similarly s_o if $M_o < 0.3$.

the computation is $\sigma_x = s_x d$

$$\sigma_o = s_o d$$

However, if $M_x \geq 0.3$ then

$$\sigma_x = 1.62d (M_x + 0.029) \sqrt{\frac{N_x}{N_x - 1}}$$

$$\sigma_o = 1.62d (M_o + 0.029) \sqrt{\frac{N_o}{N_o - 1}}$$

B. Secondary Statistics

$$m = \frac{N_o m_o + N_x m_x}{N_o + N_x}$$

$$\sigma = \sqrt{\frac{N_o \sigma_o^2 + N_x \sigma_x^2}{N_o + N_x}}$$

ζ = Antilog m ; m equals the mean or 50% firing level
and σ equals the standard deviation.

$$S = \frac{\sigma}{d}$$

$$N = N_o + N_x$$

$$n = \frac{N}{2} \quad \text{when } N \text{ is an even integer}$$

$$= \frac{N + 1}{2} \quad \text{when } N \text{ is an odd integer}$$

C. Confidence Interval (Y)

$$Y = k_E \cdot \left(\frac{n + 1.2}{n} \right) \left(\frac{G^2 + H^2 k_p^2}{n} \right)^{1/2} \sigma$$

where k_E , k_p , G and H are obtained from the Bruceton Report.

k_E and k_p are found in the table on Page 19 and G and H from Graphs III, IV and V. The table, in its entirety, is incorporated in the program, and 17 points are taken from each of the graphs and placed on data cards 1 and 2. (S = .2, .3, ..., 1.0, 1.5, 2.0, ..., 5.0). Straight line interpolations are made for values between these points.

D. Final Calculations

$$P\% (E\% \text{ confidence}) = m + k_p + Y$$

$$(100-P)\% (E\% \text{ confidence}) = m - k_p + Y$$

REFERENCES

1. AMP Report No. 101.R, Statistical Analysis for A New Procedure in Sensitivity Experiments ("Bruceton Report"), July 1944.
2. Paul R. Mohrbach and Robert F. Wood, The Franklin Institute Laboratory Memorandum Report LM-A-2369-2, Methods and Equipment for RF Sensitivity Evaluation of Electro-explosive Devices, October 1961.

APPENDIX

APPENDIX A

FORTRAN PROGRAM FOR A BRUCETON ANALYSIS

BRUCETØN STATISTICAL ANALYSIS

```

LCGF(W) = 0.4343*LOGF(W)
ANTF(W) = EXPF(W/0.4343)
DIMENSION G(50),H(50),X(50),IDENT(20),FIX(50),FAX(50),Y(50),AB(30,
115)
1 READ INPUT TAPE 2,2,(G(I),I=2,10),G(15),G(20),G(25),G(30),G(35),G(
140),G(45),G(50)
2 FØRMAT(17F4.3)
3 READ INPUT TAPE 2,4,(H(I),I=2,10),H(15),H(20),H(25),H(30),H(35),H(
140),H(45),H(50)
4 FØRMAT(17F3.2)
  READ INPUT TAPE 2,7,((AB(J,I),J=5,30),I=1,11)
7 FØRMAT(36F2.0/36F2.0/36F2.0/36F2.0/36F2.0/36F2.0/36F2.0/36F2.0)
5 READ INPUT TAPE 2,6,(IDENT(J),J=1,20),N,C,D,P,E,(X(I),FIX(I),FAX(I
1),I=1,N)
6 FØRMAT(20A1,15,2F10.0,5F5.0,2X/(14F5.0,2X))
  P1 = 100.-P
  AFIX = 0.0
  AFAX = 0.0
  BFIX = 0.0
  BFAX = 0.0
  SFIX = 0.0
  SFAX = 0.0
  I = 0
10 W = I
  AFIX = AFIX + W*FIX(I+1)
  AFAX = AFAX + W*FAX(I+1)
  BFIX = BFIX + (W**2)*FIX(I+1)
  BFAX = BFAX + (W**2)*FAX(I+1)
  SFIX = SFIX + FIX(I+1)
  SFAX = SFAX + FAX(I+1)
  I = I+1
  IF(I-N+1) 10,10,11
11 R = 0
  TFIX = ((SFIX*BFIX)-AFIX**2)/(SFIX**2)
  TFAX = ((SFAX*BFAX)-AFAX**2)/(SFAX**2)
13 UFIX = C+R*(AFIX/SFIX-0.5)
  UFAX = C+R*(AFAX/SFAX+0.5)
  IF(TFIX-0.3) 118,23,23
118 CIX = TFIX*100.
  LIX = CIX
111 WEEIX = 500.
  I = 0
112 WEEIX = MIN1F(WEEIX,ABSF(UFIX-LCGF(X(I+1))))
  I = I+1
  IF(I-N+1) 112,112,113
113 RIX = ABSF(WEEIX/R)
  KIX = XINTF(RIX*22.)+1
  VFIX = (AB(LIX,KIX)/100.)*R
24 IF(TFAX-0.3) 117,25,25
117 CAX = TFAX*100.
  LAX = CAX
114 WEEAX = 500.
  I = 0
115 WEEAX = MIN1F(WEEAX,ABSF(UFAX-LCGF(X(I+1))))
  I = I+1

```

PAGE 1

BRUCETON STATISTICAL ANALYSIS

```

IF(I-N+1) 115,115,116
116 RAX=ABSF(WEEAX/R)
    KAX=XINTF(RAX*22.)+1
    VFAX=(AB(LAX,KAX)/100.)*R
    GØ TØ 26
23 VFIX= 1.62*R*(TFIX+0.029)*SQRTF(SFIX/(SFIX-1.))
    GØ TØ 24
25 VFAX= 1.62*R*(TFAX+0.029)*SQRTF(SFAX/(SFAX-1.))
26 U =((SFAX*UFAX)+(SFIX*UFIX))/(SFAX+SFIX)
    V = SQRTF(-(SFAX*(VFAX**2)+SFIX*(VFIX**2))/(SFAX+SFIX))
    ZETA=ANTF(U)
    IF(99.-P) 51,50,50
50 KP=99.9-P
    GØ TØ 60
51 KP=(100.-P)*100.
60 IF(99.-E) 53,52,52
52 KX=99.9-E
    GØ TØ 61
53 KX=(100.-E)*100.
61 Y(49)=0.0
    Y(24)=0.675
    Y(9)=1.282
    Y(4)=1.645
    Y(0)=2.326
    Y(10)=3.090
    Y(1)=3.719
    S= V/R
    Z = S*10.
    SX= SFIX+SFAX
    SX2 =(SX+1.)/2.
    KS2 = SX2
    SX3 = KS2
    IF(Z-2.)100,14,14
14 IF(Z-50.)15,15,100
15 IF(Z-2.)100,16,16
16 IF(Z-10.)40,17,18
17 K=Z
    A=G(K)
    B=H(K)
    GØ TØ 19
40 K=Z
    S2=K
    A=(G(K+1)-G(K))*(Z-S2) + G(K)
    B=(H(K+1)-H(K))*(Z-S2) + H(K)
    GØ TØ 19
18 S1= Z/5.
    K1= S1
    K=5*K1
    S2=K
    A =((G(K+5)-G(K))/5.)*(Z-S2)+ G(K)
    B =((H(K+5)-H(K))/5.)*(Z-S2)+ H(K)
19 T =Y(KX)*((SX3+1.2)/SX3)*SQRTF((A**2+(B**2)*(Y(KP)**2))/SX3)*V
    CFL1 =U+Y(KP)*V+T
    CFL2 =U-Y(KP)*V-T
    CFN1 = ANTF(CFL1)
    CFN2 =ANTF(CFL2)

```

PAGE 2

BRUCETON STATISTICAL ANALYSIS

```

WRITE OUTPUT TAPE 3,20,(IDENT(J),J=1,20),P,E,(X(I),FIX(I),FAX(I),I
1=1,N)
20 FORMAT(1H1,10X,20A2,5X,13HPRØB. LEV. = F7.3,5X,13HCØNF. LEV. = F7.
13//10X,11HTEST LEVELS,5X,12HNØ.ØF FIRES,5X,11HNØ.ØF FAILS//(10X,F7
2.3,10X,F7.3,10X,F7.3))
WRITE OUTPUT TAPE 3,21,SFAX,SFIX,C,R,AFAX,AFIX,BFAX,BFIX,TFAX,TFIX
1,UFAX,UFIX,VFAX,VFIX,U,V,ZETA,P,P1,E,S,SX,SX3,Y(KP),Y(KX),A,B,T,P,
2E,CFL1,CFN1,P1,E,CFL2,CFN2
21 FORMAT(1H0,10X,9H NØ,NX = 2F11.5//26H SPECIAL PARAMETERS C,D = 2F1
11.5/66H PRIMARY STATISTICS      AØ,AX,BØ,BX,MØ,MX,MØ1,MX1,SIGMAØ,SI
2GMAX = ///5(13X,F11.5,5X,F11.5//),10X///45H SECONDARY STATISTICS ME
3AN,STAND.DEV.,ZETA = 3F11.5//16H PRØB. LEVELS = 2F11.5,14HCØNF. LE
4VEL = F11.5/5X,19HS,N,N1,KP,KX,G,H = /10X,6(F11.5,3X)/10X,F11.5,3X
5/25H CØNFIDENCE INTERVAL Y = F11.5//(1X,F7.3,5H WITH,F7.3,8H CØNF
6= F11.5,9HLØG UNITS,4H = F11.5//)
GØ TØ 102
100 WRITE OUTPUT TAPE 3,90,(IDENT(J),J=1,20),P,E,(X(I),FIX(I),FAX(I),I
1=1,N)
90 FORMAT(1H1,10X,20A2,5X,13HPRØB. LEV. = F7.3,5X,13HCØNF. LEV. = F7.
13//10X,11HTEST LEVELS,5X,12HNØ.ØF FIRES,5X,11HNØ.ØF FAILS//(10X,F7
2.3,10X,F7.3,10X,F7.3))
WRITE OUTPUT TAPE 3,91,S
91 FORMAT(1H0,10X,44HTHIS ANALYSIS WAS NØT CØPLETED BECAUSE S * F11.
15,103H IT IS ØUT ØF THE RANGE FRØM .2 TØ 5 AND HENCE G AND H CANNØ
2T BE DETERMINED. CHECK LEVEL DISTRIBUTIØN.)
102 GØ TØ 5
END(1,1,0,0,0,0,1,1,0,0,0,0,0,0,0)

```

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ABSTRACT DATA

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Picatinny Arsenal, Dover, New Jersey

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listings. Unclassified memorandum from the
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Engineering Directorate.

A digital computer program was developed for
performing a statistical analysis of sensitivity
data obtained from the Bruceton Test on an IBM
709 or 7090 Computer.

The input and output format are discussed as
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- I. McMains, Forrest L.
- II. Bruceton sensitivity
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